



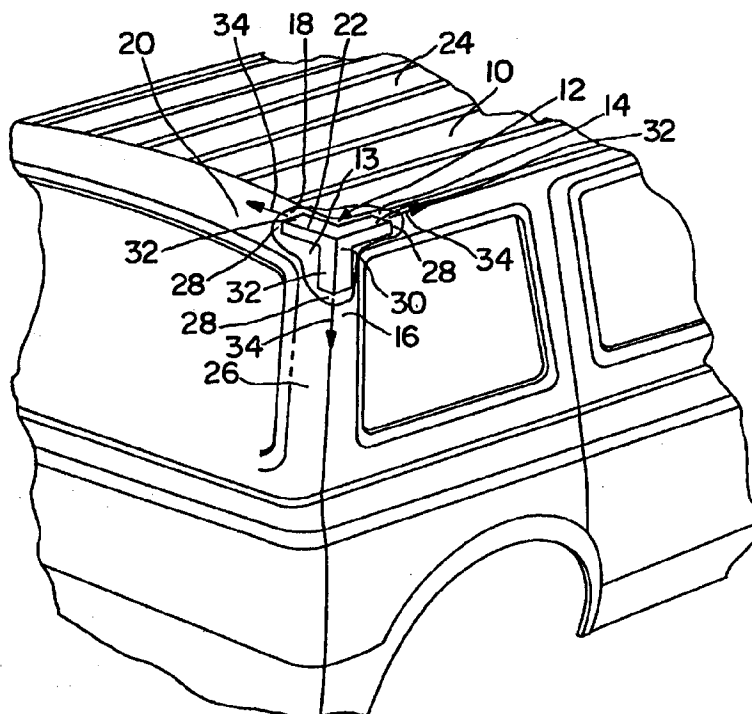
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(21) International Application Number: PCT/US99/01855 (22) International Filing Date: 3 February 1999 (03.02.99) (30) Priority Data: 09/018,387 4 February 1998 (04.02.98) US (71) Applicant: HENKEL CORPORATION [US/US]; Suite 200, 2500 Renaissance Boulevard, Gulph Mills, PA 19406 (US). (72) Inventor: WYCECH, Joseph, S.; 795 Hidden Lane, Grosse Point Woods, MI 48236 (US). (74) Agent: HARPER, Stephen, D.; Henkel Corporation, Suite 200, 2500 Renaissance Boulevard, Gulph Mills, PA 19406 (US).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>

(54) Title: THREE DIMENSIONAL COMPOSITE JOINT REINFORCEMENT FOR AN AUTOMOTIVE VEHICLE

(57) Abstract

The joint reinforcement member (30) for a hollow structure of an automobile vehicle (13) has a carrier portion (22) with an outer surface. The carrier portion has a base portion (30) with a first extension having a first longitudinal axis and a second extension having a second longitudinal axis. The first longitudinal axis and second longitudinal axis correspond to the hollow structure. A thermally expandable adhesive layer (38) is disposed on the outer surface of the carrier portion and substantially covers the outer surface. A method for forming the joint member includes providing a carrier having a plurality of extensions extending from a base portion that correspond to the hollow structure, applying a layer of thermally expandable adhesive materials applied to the carrier portion. The carrier portion is heated to activate the adhesive layer. The adhesive layer is cooled so that the adhesive is bonded to the structural member.



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THREE DIMENSIONAL COMPOSITE JOINT REINFORCEMENT FOR AN AUTOMOTIVE VEHICLE

TECHNICAL FIELD

The present invention relates generally to reinforcement of hollow structural members and, more specifically, to reinforcement of hollow structures of automotive vehicles that are generally inaccessible after assembly.

BACKGROUND OF THE INVENTION

Impact resistance, fuel economy standards and structural rigidity are important fundamental concerns in automotive structural design. Fuel economy standards dictate the use of lighter materials. This usually translates into reducing the thickness of materials or using lighter weight material. Impact resistance dictates the use of thicker materials at least in localized areas. Structural rigidity also typically requires an increase of material.

The use of composite materials which are generally stronger and lighter than their metallic counterparts has increased over the years. The present inventor has pioneered a novel approach to structural part reinforcement through localized reinforcement of critical regions using microsphere-filled thermally expandable resins, such as: composite door beam which has a resin based core that occupies one-third of the bore of a metal tube; a hollow laminate beam characterized by high stiffness-to-mass ratio and having an outer portion which is separated from an inner tube by a thin layer of structural foam; a W-shaped carrier insert reinforcement which carries a foam body for use in reinforcing a hollow beam; a bulk head that utilizes a thermally expandable foam to provide localized reinforcement of a rail for the attachment of an engine cradle or the like.

Joints of an automotive vehicles are the weakest part of the structure. Stiffening the joint improves the overall stiffness in ride characteristics of the vehicle. In the formation of the automotive vehicle body, several structural/body panel members are welded or bonded together. The joints typically are hollow by their very nature. The hollow structure allows the flow of E-coat through the structural members to increase corrosion resistance. Various techniques have been used by automotive manufacturers to increase the rigidity of the joints of the vehicle. Typically, the solutions have involved substantially increasing the bulk, size and/or complexity of the joints to thereby increase rigidity. By increasing the bulk of the joints, precious packaging space has been reduced. Also, the weight of the structure due to its bulk has been increased.

SUMMARY OF THE INVENTION

It is therefore one object of the invention to reinforce a joint of an automotive vehicle without having to increase the amount of sheet metal required in the joint.

In one aspect, the present invention provides a carrier portion having an outer surface. The outer surface has a plurality of extensions that conform to the joint into which the joint reinforcement is to be placed. An adhesive layer is disposed on the outer surface of the carrier portion. The outer surface is substantially covered by the adhesive layer. The adhesive layer is formed of a thermally expandable resin material.

In another aspect, the invention provides a method of forming a reinforcement member. The method comprises the steps of providing a carrier portion; applying a layer of adhesive material to the carrier portion; heating the carrier portion and the adhesive portion; and bonding the adhesive portion to the structural member.

In yet another aspect, the present invention provides a method of forming an automotive body having at least two body members. The assembly of the body members

5 defines a hollow space therebetween. The method includes the steps of forming a reinforcement member by applying a layer of adhesive material to a carrier portion; inserting the reinforcement member in the hollow space; and heating the body members and the carrier portion with the adhesive layer so that the adhesive material bonds to the body members.

10 One advantage of the present invention is that a reduced packaging space can be provided for the body members. This is in part due to the fact that a lower gauge sheet metal may be utilized in all the body members since the structural joints have been reinforced. This results in a desirable overall reduction in weight of the automotive vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

15 Other features and advantages of the invention will become apparent from the Detailed Description which should be read in conjunction with the drawings in which:

Figure 1 is a cutaway perspective view of an automotive vehicle having a structural reinforcement member;

20 Figures 2a and 2b are perspective views of two portions of a carrier member;

Figure 3 is a perspective view of a carrier wrapped with an adhesive layer;

Figure 4 is a plan view of a sheet of adhesive material to be applied to a carrier;

25 Figure 5 is a cross-sectional view of a carrier within a mold;

Figure 6 is a cross-sectional view of a reinforcement member in a hollow structure of an automotive vehicle; and

Figure 7 is an alternative cross-sectional view of a reinforcement member having a foam interior in a hollow structure of an automotive vehicle.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

5 In the following figures, like reference numerals will be used to represent like components. The figures illustrate a carrier member having a particular shape. Other shapes and sizes for a joint reinforcement, however, would be evident to those skilled in the art based on the teachings herein.

10 Referring now to Figure 1, an automotive vehicle 10 is shown having a joint 12. Joint 12 is a hollow structure 13 defined by inner rear quarter panel 14, outer rear quarter panel 16, inner door panel 18 and outer door panel 20. A reinforcement member 22 is inserted within hollow structure 13 to strengthen joint 12. Although reinforcement member 22 is shown illustrated within a particular joint, the present invention has application to the many joints of an automotive vehicle. As shown, the reinforcement member extends between the roof 24 and D-pillar 26. Reinforcement member 22 is particularly suitable for reinforcing the area where three hollow channels 28 intersect. However, a modified reinforcement member 22 may also be suitable for reinforcing the intersection of two channels. Reinforcement member 22 has a body portion 30 and three extension portions 32. Each extension portion 32 has a longitudinal axis 34. Longitudinal axes 34 preferably coincide with the elongated axis of each of channels 28. That is, reinforcement members 22 may be constructed so that longitudinal axes 34 are at various angles with respect to each other. Longitudinal axes 34 may be perpendicular to each other to coincide with channels 28 to correspond to the various angles of an automotive vehicle design.

25 The length of extension portions 32 from body portions 30 are a function of the amount of joint 12 to be reinforced. Various distances may be reinforced within channels

28 depending on the body structure into which reinforcement member 22 is applied. In most applications, extension portions 32 will extend several inches from body portion 30.

As shown, extension portions 32 have a generally square cross-section. However,
5 it is preferred that extension portions 32 be shaped similarly to that of channels 28. In this manner, a better fit may be achieved between reinforcement member and channels 28.

Referring now to Figures 2A, 2B and 3, reinforcement member 22 is preferably
10 formed of a carrier 36 wrapped by an adhesive layer 38. Carrier 36 is preferably formed of a thin material capable of supporting adhesive layer 38. The amount of support provided by carrier 36 is enough so that reinforcement member 22 may be handled and placed into the hollow structure of the automotive vehicle during manufacturing without deforming. Carrier 36 may, for example, be formed of a metallic material such as an aluminum sheet,
15 a steel sheet or an aluminum foil. Suitable thicknesses of such material may be, for example, .007 - .015 inches thick, .006 - .025 inches thick and .002 - .006 inches thick respectively. Other materials suitable for use as a carrier are injected molded glass filled nylon, .062 - .25 inches thick, blow molded or rotational molded high temperature plastic,
20 .06 - .25 inches thick (abs or polystyrene) or rotational molded or cast cement foam, .25 - .5 inches thick. Of course, the various thicknesses may vary depending on the particular circumstances.

Several methods for forming carrier 36 may be used depending on the carrier
material. As illustrated in Figures 2A and 2B, two pieces of aluminum or steel may be stamped to form two halves 40 and 42 of carrier 36. Halves 40 and 42 may then be welded
25 or snapped together to form carrier 36. As shown, half 40 has ends 44 along each extension portion 32. In the preferred embodiment, though, carrier 36 either does not have ends 44 or has holes within ends 44 to allow the passage of E-coat during manufacturing to increase corrosion protection. The addition of ends 44, however, further increases the strength of carrier 36.

Carrier 36 may also be formed by placing a foil backed sheet over a foam three-dimensional core. Carrier 36 may also be formed by blow molding, injection molding, casting foam cement around a Styrofoam core, or utilizing an "aluminum can" or shell as the internal carrier with processes based on techniques for forming aluminum beverage cans.

5 Carrier 36 may also be formed by hydroforming a metal into a three-dimensional shape.

After or during the formation of carrier 36, metal extensions such as pins 46 or metal tabs may be added to carrier 36. Pins 46 align with holes in or near joints 12. The number of pins 46 may vary with each application. The pins locate reinforcement member 22 within

10 channels 28 during assembly of the vehicle. Channels 28 may have holes therethrough that align with pins 46.

The polymer used to form adhesive layer 22 is a resin-based material which is thermally expandable. A number of resin-based compositions can be utilized to form

15 adhesive layer 38 in the present invention. The preferred compositions impart excellent strength and stiffness characteristics while adding only marginally to the weight. With specific reference now to the composition of adhesive layer 38, the density of the material should preferably be from about 20 pounds per cubic foot to about 50 pounds per cubic foot to minimize weight. The melting point, heat distortion temperature, and the temperature at

20 which chemical breakdown occurs must be sufficiently high such that adhesive layer 38 maintains its structure at high temperatures typically encountered in paint ovens and other vehicle assembly processing. Therefore, adhesive layer 38 should be able to withstand temperatures in excess of 320°F., and preferably 350°F. for short times. Also, adhesive layer 38 should be able to withstand in final service heats of about 90°F. to 200°F. for

25 extended periods of time without exhibiting substantial heat-induced distortion or degradation.

In more detail, in one particularly preferred embodiment, the thermally expanded structural foam of adhesive layer 38 includes a synthetic resin, a cell-forming agent, and a

filler. A synthetic resin comprises from about 40% to about 80% by weight, preferably from about 45% to about 75% by weight, and most preferably from about 50% to about 70% by weight of adhesive layer 38. Most preferably, a portion of the resin includes a flexible epoxy. As used herein, the term "cell-forming agent" refers generally to agents which produce bubbles, pores, or cavities in adhesive layer 38. That is, adhesive layer 38 has a cellular structure, having numerous cells disposed throughout its mass. The cellular structure provides a low density, high strength material, which provides a strong, yet light-weight structure. Cell forming agents which are compatible with the present invention include reinforcing "hollow" microspheres or microbubbles which may be formed of either glass or plastic. Glass microspheres are particularly preferred. Also, the cell-forming agent may comprise a blowing agent which may be either a chemical blowing agent or a physical blowing agent. Where the cell-forming agent comprises microspheres or macrospheres, it constitutes from about 10% to 50% by weight, preferably from about 15% to about 40% by weight, and most preferably from 20% to about 40% by weight of the material which forms adhesive layer 22. Where the cell-forming agent comprises a blowing agent, it constitutes from about .5% to about 5.0% by weight, preferably from about 1% to about 4.0% by weight, and most preferably from about 1% to about 3% by weight of adhesive layer 38. Suitable fillers include glass or plastic microspheres, fumed silica, cathium carbonate, milled glass fiber, and chopped glass strand. A thixotropic filler is particularly preferred. Other materials may be suitable. The filler comprises from about 1% to about 15% by weight, preferably from about 2% to about 10% by weight, and most preferably from about 3% to about 8% by weight of adhesive layer 38.

Preferred synthetic resins for use in the present invention include thermosets such as epoxy resins, phenol ester resins, thermoset polyester resins, and urethane resins. It is not intended that the scope of the present invention be limited by molecular weight of the resin and suitable weights will be understood by those skilled in the art based on the present disclosure. Where the resin component of the liquid filler material is a thermoset resin, various accelerators such as imidizoles and curing agents, preferably dicyandiamide may

also be included to enhance the cure rate. A functional amount of accelerator is typically from about .5% to about 2.0% of the resin weight with corresponding reduction in one of the three components, resin, cell-forming agent or filler. Similarly, the amount of curing agent is typically from about 1% to about 8% of the resin weight with a corresponding reduction in one of the three components, resin, cell-forming agent or filler. Effective amounts of processing aids, stabilizers, colorants, UV-absorbers and the like may also be included in the layer. Thermoplastics may also be suitable.

In the following table, a preferred formulation for adhesive layer 38 is set forth. It has been found that this formulation provides a material which fully expands and cures at about 320°F. and provides excellent structural properties. All percentages in the present disclosure are percent by weight unless otherwise specifically designated.

<u>Ingredient</u>	<u>% by Weight Range</u>	<u>Preferred Percentage</u>
EPON 828 (epoxy resin)	30-40	36.96
DER 331 (flexible epoxy resin)	10-20	15.06
AMICURE CGNA (curing agent)	3.5-4.6	4.12
AMICURE VR (accelerator)	.4-1.2	.80
TS720 (thixotropic filler)	.5-1.5	1.1
CELOGEN AZ 199 (azodicarbonamide blowing agent)	.7-1.8	1.21
B38 MICROS (glass microspheres)	30.0-45.0	37.16
WINNOFIL CALCIUM CARBONATE (C _a CO ₃ filler) or CARBON BLACK	.1-1.1	.6
NIPOL 1312 (liquid rubber)	2.0-4.0	3.01

In addition colorings and other additives may be included such as Phtalocyanine blue and KR55.

Adhesive layer 38 in most applications is a layer extending around or substantially around the entire outer surface of carrier 36. It is preferred that adhesive layer 38 is of relatively uniform thickness, for example, from about 2 to about 6 mm, in the unexpanded state.

Referring now to Figure 4, adhesive layer 38 may be prepared by die cutting a sheet 48 of resin to the required geometry. The die cut portion 50 is then wrapped around the three-dimensional carrier 36. Alternatively, other forms of coating carrier 36 may be used. For example, adhesive layer 38 may be applied by spraying or compression molding.

Referring now to Figure 5, another method for applying adhesive layer 38 to carrier 36 is by the use of a mold 52. Carrier 36 is located within a mold 52. A gap 54 between mold 52 and carrier 36 is preferably uniform and sized to the desired thickness of adhesive layer 38. A port 56 is provided through mold 52 so that molten adhesive layer material may be injected into gap 54 to surround carrier 36.

It is preferred that mold 52 is cooled and polished to ease part release. This may be done in several manners such as by running coolant fluids through mold body 52. By cooling mold 52, separating adhesive layer 38 from mold 52 is simplified.

Referring now to Figure 6, a cross-sectional view of a reinforcement member 22 formed according to Figures 3, 4 or 5 as shown. Adhesive layer 38 is applied uniformly around carrier 36. Carrier 36 is preferably hollow and generally conforms to channel 28. Adhesive layer 38 has the characteristics that when the vehicle is subjected to paint baking, adhesive layer 38 expands and bonds to channels 28. Thus, after adhesive layer 38 cools, the adhesive layer 38 bonds to channels 28 to reinforce joint 12. Because the joints of vehicle are structurally reinforced, vehicle stiffness and ride characteristics are improved which allow for weight reduction by reducing the gauge of metal provided to form the body panels of the vehicle.

Referring now to Figure 7, a cross-sectional view of an alternative method for forming reinforcement member 22 is shown. Instead of having a hollow shell as in Figure 6, carrier 36 is formed having a foam core 58. A foil or metallic layer forms carrier 36. For example, an aluminum foil may be wrapped around foam core 58. Using a form core 58, adhesive layer 38 may be applied in any of the above specified manners. Foam core 58 is preferably formed of a thermally activated or fugitive material. That is, when the foam core is subject to heat, the form core breaks down to leave a hollow carrier 36. The heat preferred for foam core 58 to break down is at a maximum temperature to which the vehicle is subject to during paint bake operation. By using a foam core 58, a slightly more rigid reinforcement member 22 is obtained and thus reinforcement member 22 may be easier to handle during vehicle assembly, especially when foil carriers are used.

In operation, reinforcement members 22 as described above would likely be supplied to automotive vehicle assembly plants. Reinforcement members may be manufactured according to any of the methods set forth above. During the assembly of the vehicle body and before welding or masticing of the various body panels, reinforcement members would be placed at various joints of the vehicle. Preferably, any joints and adhesive layer 38 align with any of the seams in the body of the vehicle. After the reinforcement members 22 are inserted in the joints, the body panels are joined together. Commonly, the vehicle body once welded together is subjected to E-coat. During E-coat, the body is dipped into a pool of E-coat. E-coat flows through the hollow reinforcement member 22 to coat the body including the interior of channels 28.

Subsequently, paint is then applied to the body panels. After paint is applied to the body panels, the paint is baked. During this baking process, the temperature of the body panels is substantially raised. Commonly, body temperatures exceed 325°F. The temperature of the interior of channels 28 also is raised to that temperature. This temperature then activates the adhesive layer 38 so that it expands and bonds with the

interior of the body panels within channels 28. When cooled, reinforcement member 22 is bonded to the body panels and the joint is then reinforced.

5 While the best mode for carrying out the present invention has been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments for practicing the invention as defined by the following claims.

What is claimed is:

1. A joint reinforcement member for hollow structure of an automotive vehicle comprising:

5 a carrier portion having an outer surface, said carrier portion having a base portion having a first extension having a first longitudinal axis extending therefrom and having a second extension having a second longitudinal axis extending therefrom, said first longitudinal axis and said second longitudinal axis corresponding to said hollow structure; and,

a thermally expandable adhesive layer disposed on said outer surface and substantially covering said outer surface.

2. A joint reinforcement member as recited in claim 1, wherein said first longitudinal axis is perpendicular to said second longitudinal axis.

3. A joint reinforcement member as recited in claim 1, wherein said carrier portion comprises a third extension extending from said base portion, said third extension having a third longitudinal axis.

4. A joint reinforcement member as recited in claim 3, wherein said third longitudinal axis is substantially perpendicular to said first and second longitudinal axis.

5. A joint reinforcement member as recited in claim 1, wherein said carrier portion is hollow.

6. A joint reinforcement member as recited in claim 1, wherein said outer surface having a metallic layer.

7. A joint reinforcement member as recited in claim 1, wherein said carrier has metal extensions extending therefrom.

8. A joint reinforcement member as recited in claim 1, wherein said carrier having through holes.

9. A joint reinforcement member as recited in claim 1, wherein said carrier portion comprises two stamped metal channels coupled together.

10. A joint reinforcement member as recited in claim 1, wherein said carrier portion comprises a foil coated foam member, said foil forming said outer surface.

11. A joint reinforcement member as recited in claim 10, wherein said foam member is heat activated.

12. A joint reinforcement member as recited in claim 1, wherein said adhesive layer comprises by percentage weight,

epoxy resin	between about 30 and about 40,
flexible epoxy resin	between about 10 and about 20,
curing agent	between about 3.5 and about 4.6,
accelerator	between about .4 and about 1.2,
thixotropic filler	between about .5 and about 1.5,
blowing agent	between about .7 and about 1.8,
glass microspheres	between about 30.0 and about 45.0,
filler	between about .1 and about 1.1, and
liquid rubber	between about 2.0 and about 4.0.

13. A method of forming a reinforcement member for placement within a hollow structure member of an automotive vehicle comprising:

providing a carrier portion having a plurality of extensions extending from a base portion corresponding to the hollow structure;

5 applying a layer of thermally expandable adhesive material to said carrier portion;

heating the carrier portion and the adhesive layer;

activating the adhesive layer;

bonding the adhesive layer to a structural member; and

10 cooling the structural member and the adhesive layer.

14. A method of forming a reinforcement member as recited in claim 13, further comprising the step of cutting the adhesive layer from a sheet of adhesive material.

15. A method of forming a reinforcement member as recited in claim 13, wherein the step of applying the layer of adhesive further comprises the sub-steps of placing the carrier portion in a mold; injecting the adhesive layer between the carrier portion and the mold; and, removing the carrier portion having the adhesive layer from the mold.

16. A method of forming a reinforcement member as recited in claim 15, further comprising the step of chilling the mold.

17. A method of forming an automotive body having at least two elongated hollow body members, the assembly of said body members defining a hollow space therebetween comprising:

5 inserting a reinforcement member in the hollow space, the reinforcement member having a carrier portion having an outer surface and a base portion having a first extension having a first longitudinal axis extending therefrom and having a second extension having a second longitudinal axis extending therefrom, the outer surface of the carrier having a thermally expandable adhesive layer disposed thereon;

10 aligning the first extension with the one of the hollow body members;

aligning the second extension with the other of the hollow body members;

heating the body members, the carrier portion and the adhesive layer;

bonding the adhesive material within the hollow body members; and

cooling the structural member and the adhesive layer.

18. A method of forming an automotive body as recited in claim 17, further comprising the steps of forming the adhesive layer by cutting the adhesive layer from a sheet of adhesive material.

19. A method of forming an automotive body 18, further comprising the step of applying the layer of adhesive to the carrier.

20. A method of forming an automotive body 17, wherein the step of applying the layer of adhesive to the carrier comprises the sub-steps of placing the carrier portion in a mold; injecting the adhesive layer between the carrier portion and the mold; and, removing the carrier portion having the adhesive layer from the mold.

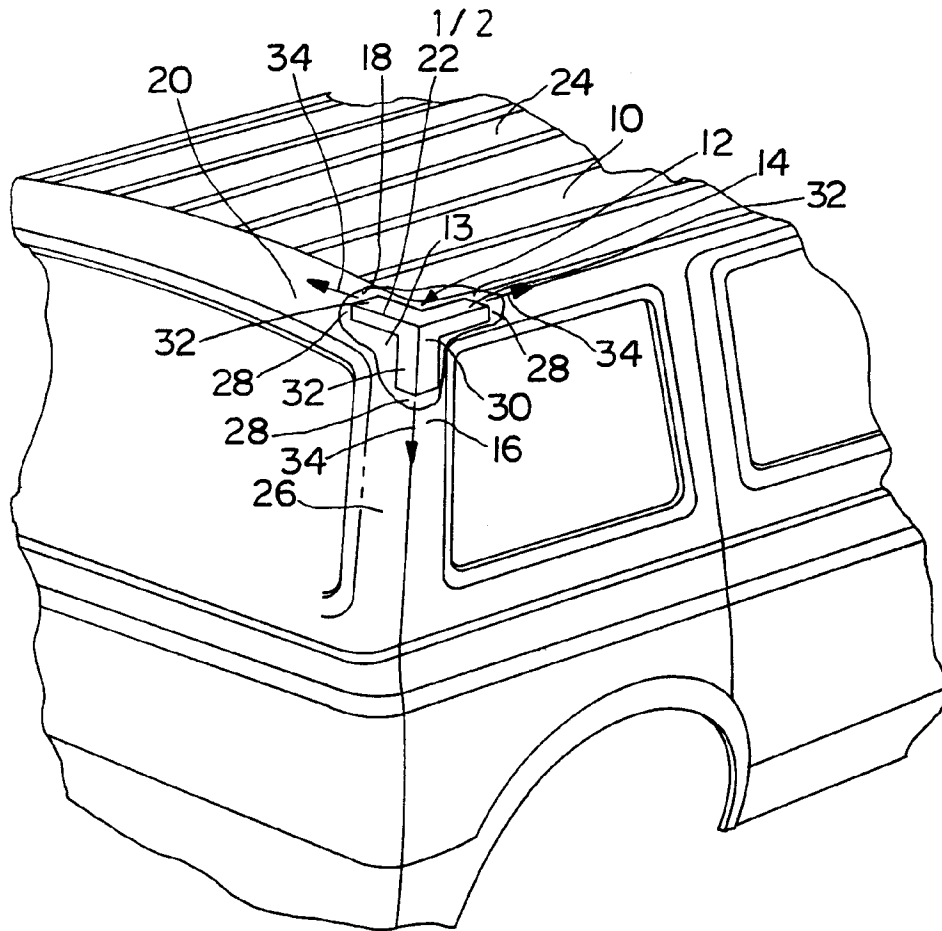


FIG. 1

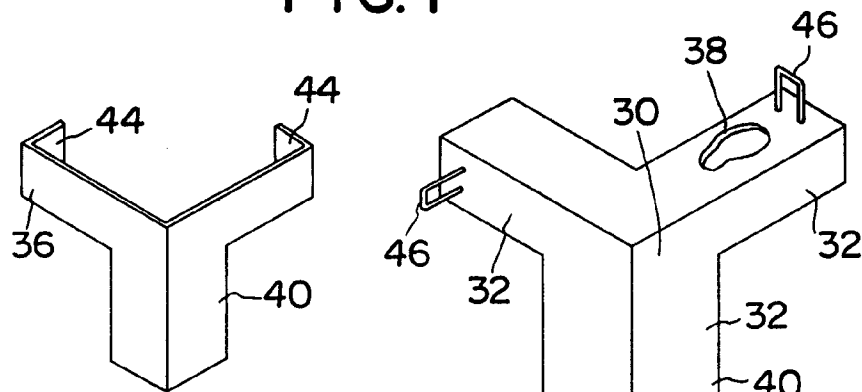


FIG. 2A

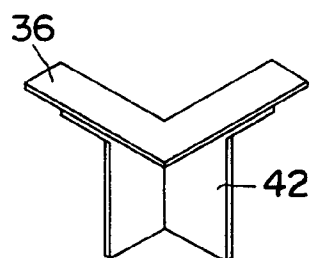
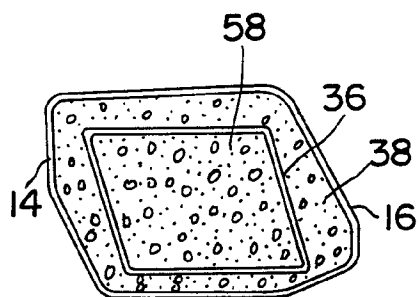
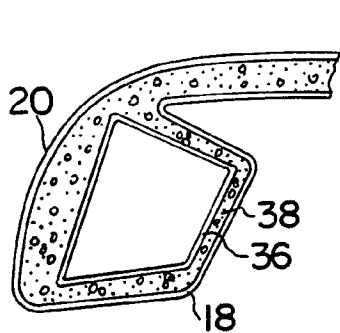
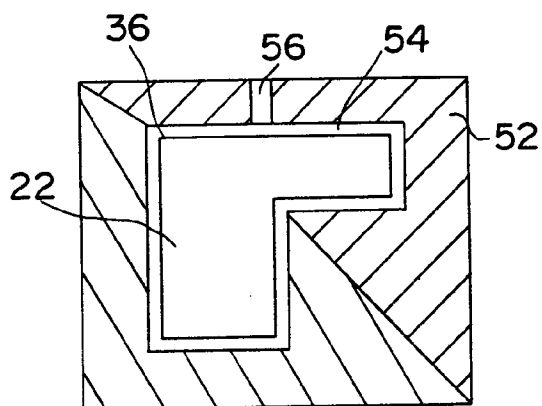
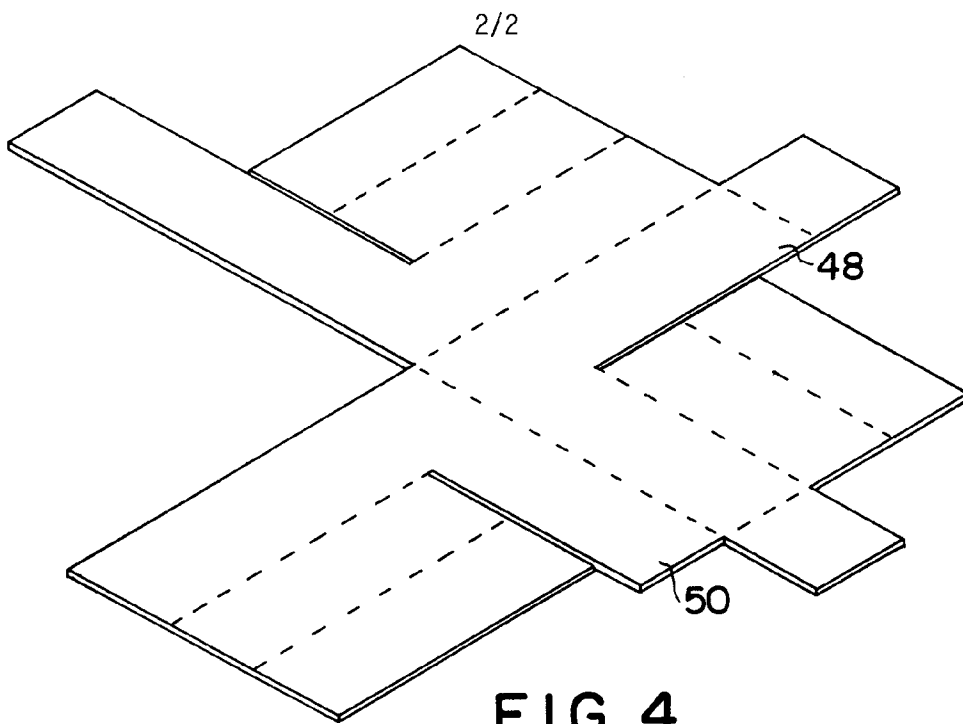


FIG. 2B

FIG. 3



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/01855

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : B 25 G 3/34

US CL : 403/268

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 403/265, 266, 267, 268, 269, 171, 176; 296/187, 30.29, 203.01; 156/79, 293, 294

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2,206,537 (YUKIO) 16 AUGUST 1990 (16.08.90) SEE ENTIRE DOCUMENT	1, 5, 6, 8
A	US 4,922,596 A (WYCECH) 08 MAY 1990 (08.05.90) SEE ENTIRE DOCUMENT	1-20
X	US 5,213,391 A (TAKAGI) 25 MAY 1993 (25.05.93) SEE ENTIRE DOCUMENT	2-3, 13, 17

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Date of the actual completion of the international search

07 APRIL 1999

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